PERFORMANCE EVALUATION OF CHARCOAL BARBEQUE WITH AIR VENTILATION SYSTEM

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Thesis submitted in fulfilment of the requirements
For the award of the degree of
Bachelor of Engineering Technology in Energy and Environmental

Faculty of Engineering Technology
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2018

STATEMENT OF AWARD FOR DEGREE

1. Bachelor of Engineering Technology

Thesis submitted in fulfillment the requirements for the award of the degree of Bachelor of Engineering Technology in Energy and Environmental.

SUPERVISOR'S DECLARATION

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries in which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ACKNOWLEDGEMENTS

I am sincerely grateful to ALLAH “S.W.T” for giving me wisdom, strength, patience and assistance to complete my project work. Had it not been due to His will and favor, the completion of this study would not have been achievable.

This dissertation would not have been possible without the guidance and the help of several individuals who contributed and extended their valuable assistance in the preparation and the completion of this project. I am deeply indebted to my supervisor, Dr Nadzirah bte Mohd Mokhtar for his patient, guidance, comment, stimulating suggestions and encouragement which helped me in all the time of my project work

I also like to convey thanks to the faculty (FTEK) for providing the laboratory facilities for this project. My sincere appreciation also extends to all my friends, lecturers, teaching engineers and others who provided assistances and advices, including the crucial input for my planning and findings. The guidance and support received from all was vital for the success of this research.

Eventually, my deepest gratitude goes to my family for their support, patience, love and trust during my study. Finally, I would like to thank everyone who had involved in this study either directly or indirectly

ABSTRACT

The charcoal barbeque system developed in this project is a portable and compact barbecue set equipped with air ventilation system. The objective of this work is to analyses the heat transfer mechanism from barbequing process using this charcoal barbeque system. The main purpose of the air ventilation system is to avoid manual fanning. Besides that, some improvement features are added to reduce combustion time, safety, energy and quality of grilling with ease of use. The methodology involved the design stage of charcoal barbeque with air ventilation system prototype by using NX10 modelling. Subsequently, material selection and cost analysis have been done to identify ideal and cost-effective equipment and material based on price, size/dimension and quality. It followed by the fabrication of major components such as the body casing, charcoal port, hot rack and blower. After that, electrical part was commissioned to control the speed of blower. Three types of performance testing have been conducted to ensure the final product is well function. The blower performance testing proved that the higher the voltage, the higher the velocity. The minimum voltage supply set at 6.9V resulted velocity of blower at 17.7knott (9.1 m/s). Meanwhile maximum voltage 7.3V achieved blower velocity about 21.9knott (11.2m/s). In terms of best quality of charcoal for combustion, coconut shell charcoal is selected as more effective than mangrove wood charcoal as it capable to generate higher hot air temperature, flameless and smokeless. Theoretically, according to the heat transfer analysis, temperature difference throughout the barbecuing determines amount of heat transferred towards the food. This analysis demonstrated that heat is gradually transferred to the chicken meat throughout the barbecuing. The chicken meat received adequate heat at 74.4 °C when it is fully cooked.

ABSTRAK

Sistem barbeku arang yang dibangunkan di dalam projek ini ialah produk yang mudah alih, kompak dan dilengkapi dengan sistem pengudaraan. Objektif projek ini adalah untuk menganalisis mekanisme pemindahan haba daripada sistem barbeku yang masih menggunakan sistem arang. Tujuan utama pemasangan sistem pengudaraan adalah untuk mengelakkan sistem pengudaraan secara manual oleh pengguna. Di samping itu, sistem ini telah dilengkapi dengan beberapa ciri-ciri tambahan untuk mengurangkan masa pembakaran, ciri keselamatan, tenaga dan kualiti pembakaran makanan yang selamat untuk digunakan. Metodologi yang terlibat di dalam proses reka bentuk prototaip sistem barbeku yang dilengkapi sistem pengudaraan ini adalah menggunakan model NX10. Seterusnya, pemilihan material dan analisis kos telah dijalankan untuk menentukan alatan dan material yang ideal dan kos efektif berdasarkan harga, saiz/dimensi dan kualiti. Diikuti dengan proses fabrikasi komponen-komponen utama seperti permukaan luaran, bekas arang, rak pemanas dan juga kipas udara. Selepas itu, pemasangan komponen elektrik telah dijalankan untuk mengawal kelajuan kipas udara. Tiga jenis analisis prestasi telah dijalankan untuk memastikan produk yang dihasilkan berfungsi dengan baik. Ujian prestasi terhadap kipas udara telah membuktikan kelajuan udara semakin meningkat dengan peningkatan voltan. Voltan minimum yang telah disetkan adalah 6.9V dan menghasilkan kelajuan kipas udara 17.7knott (9.1 m/s). Manakala, voltan maksimum 7.3V menghasilkan kelajuan udara 21.9knott (11.2m/s). Di dalam aspek kualiti arang semasa pembakaran, arang daripada tempurung kelapa telah dipilih sebagai arang yang lebih efisien kerana menghasilkan udara panas yang bersuhu lebih tinggi, tidak bercela dan kurang berasap. Secara teori, berdasarkan analisis pemindahan haba, perbezaan udara sepanjang proses barbeku menentukan jumlah haba yang dipindahkan kepada makanan. Analisis ini menunjukkan bahawa haba telah dipindahkan kepada daging ayam secara beransur-ansur sepanjang proses barbeku. Daging ayam telah menerima haba yang secukupnya menunjukkan ia telah masak sepenuhnya pada suhu 74.4 °C.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Barbecuing is normally a social occasion and is a safe activity. In Malaysia, under Environmental Quality Act 1974 [Act 127] Environmental Quality (Prescribed Activities) (Open Burning) Order 2000 stated that open burning from outdoor grills, barbeques or fireplaces for the preparation of food which is not carried out at any peat soil area is allowed. Barbecuing is a great activity for bonding with family and friends. It is very popular event during leisure time. This prompts the idea to innovate a barbecue tools in this project.

A barbeque grill is a device that cook food by applying heat from below. Barbequing over charcoal grills is popular around the world. Every country has their own style of barbequing. It depends on the type of barbeque system. To that end, consumers are able to choose from a various type of charcoal grills that come in all shapes and sizes. Charcoal grills require approximately 30 minutes or more to heat the charcoal to a temperature suitable for safe and effective cooking (U.S. Patent No. 2008016897, 2008).

The grill sales trend in Figure 1.1 shows demand for barbeque products is increasing over years. Charcoal grill still being used for barbequing purpose, on top of infrared grills, kamados, gas grills and pallet grills. Thus, in 2014 data shows that 15% retailers are still using charcoal/smoker as their barbeque system.

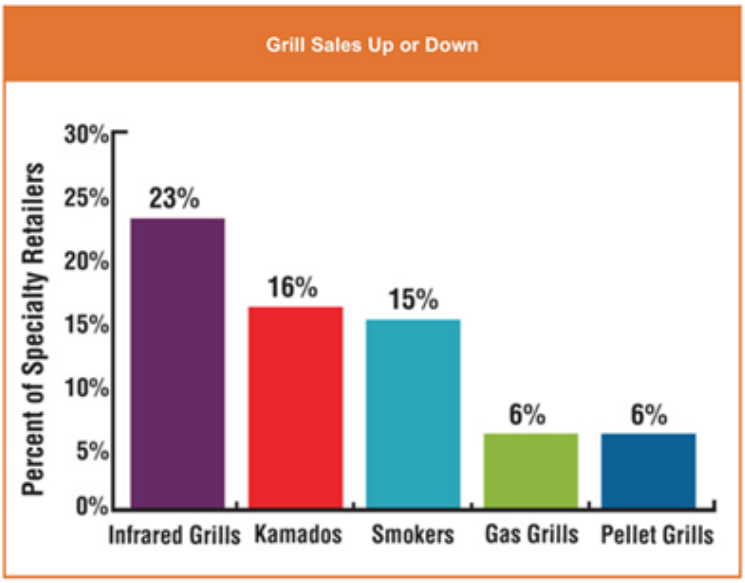

Figure 1.1: The Barbeque Grill Sales in United State 2014 (Wright, 2015)

Based on the previous research and market studies, gas and electric grills are not new after the charcoal grill. Table 1.1 provided the amount of shipments for three types of barbeque grills including charcoal, gas and electric from 2010 to 2013. Gas and electric grill shipments were increased while charcoal slightly decreased about 10.3%. People in North US were looking for other method instead of charcoal as they choose not to get expose to the smoke from charcoals. However, charcoal grill cooked meat has better acceptability, tenderness, juiciness, and flavor scores compared to those of gas and electrical grill-cooked (Choi, 2016). Moreover, people are still looking for a charcoal grill to get a smoky and natural taste of the barbecue.

Table 1.1: Shipments of Charcoal, Gas and electric Barbeque Grill Shipments in North US.

Year	Charcoal	Gas	Electric
2010	6,232,500	8,553,500	276,600
2011	6,047,000	8,445,000	288,000
2012	5,917,000	8,200,000	280,000
2013	5,590,000	8,053,000	302,000

Therefore, the charcoal grill needs to be improvised by providing a simple and easy to use device that generates an airflow that travels through the charcoals, allowing accelerated ignition and heating of the charcoal without creating potential contaminants or blowing ashes into the cooking food (U.S. Patent No. 2008016897, 2008). Thus, this project had improvised the design of conventional charcoal grill by developing a Charcoal Barbeque with Air Ventilation System as shown in Figure 1.2.

Throughout the project development, every important aspect has been considered such as the compatibility of the design with semi-auto portable concept, the air ventilation system at which the device is able to be produce and recycle heat, and the quality of barbecuing in aspect of environmental. In a nutshell, the barbeque set comes with special features that improve energy usage, time consumption, eco-friendly, ease at use and user safety.

Figure 1.2: The Charcoal Barbeque with Air Ventilation System

REFERENCES

Choi, Y.S. (2016). Comparative Study on the Effects of Boiling, Steming, Grilling, Microwaving and Superheated Steaming on Quality Characteristics of Marinated Chicken Steak. *Korean Journal Food Science* **36** (1): 1-7.

Deepika, P., Ratnakumari, D. and Mrunalini , A. (2016). Performance Efficiency Of Improved Barbecue For Roasting Corn Cobs. *International Journal of Information Research and Review* **3** (2):1860-1862.

Farid, D. (2008). *U.S. Patent No. 2008016897.* New York, US: U.S. Patent and Trademark Office.

Gyansah, L. (2012). Design, Construction and Modeling of a Mechanical Portable Barbecue Machine. *Global Journal of Researches in Engineering Mechanical and Mechanics Engineering* **12**(7) :43-58.

Harris, C. (2010). *Ohio University Bbq*. Executive Summary Design Report. Ohio University, US.

Jungmeyer, S. C. (2017). *U.S. Patent No. 20170238761*. Missouri, US: U.S. Patent and Trademark Office.

Knight, D. B. (2010). *U.S. Patent No. 20110275023.* Missouri, US: U.S. Patent and Trademark Office.

Li, F. and Guo Wang, J. (2014). *U.S. Patent No. 20140090634.* California, U.S.: U.S. Patent and Trademark Office.

Lindberg, E. (2010). *Energy Efficient Barbecue- A Minor Field Study in Namibia*. Master of Science Thesis. Royal Institute of Technology, Stockholm, Sweden.

Oke, D. P. (2013). Development of a Multi-Purpose Roasting Machine. *The Pacific Journal of Science and Technology* 14 (2):48-52.

Paul. (2018). Beginners Guide To Barbecue. Retrieved from https://www.barbecue-smoker-recipes.com/beginners-guide-to-barbecue.html

Taams, S. (2016). *Designing a connected barbecue.* Master of Industrial Design Engineering Thesis.

Wright, R. (2015). 2015 Buyer's Guide Barbeque Data. Retrieved from http://www.hearthandhome.com/magazine/2015-08-21/barbecue_data.html

Zhang, Z. (2017). Measurement of Indoor Air Quality in Chinese Charcoal Barbecue. *Procedia Engineering*, pp. 887-894.

Jenner, M. (2017). Lump Charcoal vs Briquettes – Is one Better than the Other? Why?. Retrieved from https://www.foodfirefriends.com/lump-charcoal-vs-briquettes/